Evaluation of Mine Restoration Based on The Comprehensive Empowerment Method

Jun Li *, Xiangsheng Li

School of Energy and Mining Engineering, China University of Mining and Technology-Beijing, Beijing, China, 100083

* Corresponding Author Email: lijunCUMTB@163.com

Abstract. In order to better evaluate the mine restoration, this paper establishes a comprehensive evaluation model. Firstly, G1 method and coefficient of variation method are used for comprehensive evaluation. The land state, vegetation restoration state, water environment restoration state and mine social benefit are analyzed. Secondly, the subjective and objective weight of mine restoration is used to obtain the comprehensive weight. Then, the triangular fuzzy number method is used to comprehensively consider the qualitative and quantitative indicators and obtain the comprehensive score. Finally, the final score is obtained by combining the composite score and the composite weight. According to the case analysis of the three mines, the situation of mine restoration is assessed based on the final score to provide guidance for the mine restoration project.

Keywords: Mine Restoration; G1 Method; Coefficient Of Variation Method; Comprehensive Empowerment Method.

1. Introduction

Mine restoration is an important means of environmental restoration after the completion of mining. Only by doing a good job in environmental restoration, can we properly handle the environmental problems left over after mining. Therefore, mine safety evaluation is of great significance to alleviate the impact of mining on vegetation destruction.

At present, in the evaluation of the mine after the restoration, Zhao Jinzhao [1]Using the evaluation model based on hierarchical analysis method, they set up the criterion layer from the aspects of adaptability, green recovery effect, economy and application potential to form the evaluation system. Zhang Hao used the evaluation model based on gray correlation, set the environmental soil loss, soil erosion reduction, vegetation coverage and other indicators, and used the difference coefficient to conduct comprehensive evaluation [2]. Ren Hong used the evaluation model based on the value evaluation method to achieve the comprehensive evaluation by establishing the three indicators of environmental effect, ecological effect and social and economic effect, and conducting the performance evaluation [3]. Chen Zanxu used the evaluation model of entropy right method to objectively evaluate the entropy right method on economic development, environmental governance, ecosystem resilience, and scientific and technological innovation[4]. Yin Yaqiu evaluated the geological environment of mines through remote sensing and hierarchical analysis. They first extracted the information through remote sensing, and then analyzed the indicators of natural geography, basic geology, resource damage, geological environment and other indicators through hierarchical analysis, so as to get subjective evaluation [5]. Pan Ye et al. used weighted TOPSIS method to evaluate the indexes of function of forest layer, regulating gas function, dead litter layer function, soil layer function and other [6]. Wang Xiaobing et al. evaluated the waste mine, exposed mountain, soil erosion and forest fire situation based on the fuzzy evaluation method [7]. Zhang Zhou used the AHP-fuzzy comprehensive evaluation method to evaluate the three dimensions of mine restoration, bare mountain restoration and soil erosion restoration [8]。

Most of the above research methods are purely subjective and objective evaluation and analysis, without comprehensive empowerment. Therefore, the evaluation model established based on the comprehensive evaluation method in this paper can balance the subjective and objective weight well, so as to carry out the comprehensive empowerment evaluation. Secondly, the triangular fuzzy number

method is used to calculate the index score to solve the problem that the qualitative indicators are difficult to digitize. Finally, the objective weight obtained from the subjective weight and the coefficient of variation of G1 analysis produces comprehensive weights through comprehensive treatment, and the final score is weighted. By comparing the final mine restoration scores, the mine restoration is evaluated.

2. Model introduction

2.1. Weight determination

In the study of the weight determination method of mine restoration index, there are mainly subjective empowerment method, objective empowerment method and comprehensive empowerment method. For the subjective empowerment method, the weight relies too much on the judgment of human factors, resulting in a large deviation between the weight and the actual situation. The objective empowerment law only relies on the objective data to support, and it is difficult to accurately meet the actual situation. So if we want to get accurate feedback on the actual data, we need to use comprehensive empowerment methods. This method combines both subjective and objective methods, which is of great significance to the evaluation of mine restoration.

2.1.1 Determination of subjective weights

G1 analysis method is a subjective weight determination method based on the hierarchical analysis method. Compared with the hierarchical analysis method, G1 avoids the tedious work of establishing evaluation matrix, at the same time, avoids the problem that consistency test is difficult to pass, and can get weight more concise, which is more efficient than the hierarchical analysis method [9]。

When applying G1 analysis, industry experts were first invited to rank the importance of the indicators, and then,We define r_n as the importance ratio of X_n to X_{n-1}. The specific value and the meanings represented are as follows, as shown in Table 1:

Table. 1 Table of meanings of r_n

r_n	meaning
1.0	The indicators X_{n-1} are just as important as the indicators X_n
1.1	The indicators X_{n-1} and indicators X_n are between equally important and slightly important
1.2	Indicators X_{n-1} and indicators X_n are slightly more important
1.3	Indicators X_{n-1} and indicators X_n are between slightly important and obviously important
1.4	Indicators X_{n-1} and indicators X_n are obviously important
1.5	Indicators X_{n-1} and indicators X_n are somewhere between obviously important and strongly important
1.6	Indicators X_{n-1} and indicators X_n are strongly important
1.7	Indicators X_{n-1} and indicators X_n are somewhere between strongly important and extremely important
1.8	Index X_{n-1} and indicators X_n are extremely important

Then, so we define the weight of the n th indicator as:

$$w_n = (1+\sum_{i=2}^{n}\prod_{i=n}^{n} r_i)^{-1} \tag{1}$$

w_n r_i represents the n th weight, is the importance ratio.

Finally, the weights of the other indicators are determined as follows:

$$w_{n-1} = r_n w_n \tag{2}$$

w_n represents the n th weight.

2.1.2 Objective weight determination

Coefficient of variation method is a more objective empowerment method, can avoid the weight of the weight, mainly is the current value and the target value variation degree of empowerment, if the index existing value and target value gap is larger, it shows that it is difficult to achieve or reach the target value, the index of resolution information ability rich, can be assigned with larger weight, on the other hand, gives a smaller weight. The coefficient of variation method mainly has the following parts: establishing the original matrix, the index forward direction, data standardization, the calculation and weight of the coefficient of variation [11]. As shown in Figure 1:

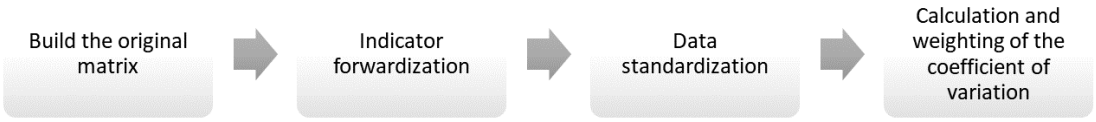


Figure. 1 Flow of the coefficient of variation method

(1) Establish the original matrix:

In the data with m metrics and n schemes, build a matrix.

$$D = \begin{pmatrix} x_{11} & \cdots & x_{1m} \\ \vdots & \ddots & \vdots \\ x_{n1} & \cdots & x_{nm} \end{pmatrix} \tag{3}$$

x_{ij} is the data in column j, row i.

(2) Positive indicators:

The data we have collected has positive data, that is, the larger the data, the more favorable, and there are negative data, that is, the bigger the data, the more unfavorable. In order to ensure that the data we use are all positive indicators, so we treat the negative indicators positively.

Treatment of the forward indicators:

$$y_{ij} = x_{ij} \tag{4}$$

y_{ij} is the indicator data after positive conversion.

Treatment of the negative indicators:

$$y_{ij} = \frac{1}{k + \max\left|x_j\right| + x_{ij}} \tag{5}$$

Where k we take 0.1, $\max\left|x_j\right|$ is the maximum value of the absolute value data in column j.

(3) Data standardization:

In order to avoid the operation of data affected by the different dimensions of data, we choose to use standardization to process data and eliminate the deviation caused by different dimensions. Therefore, we chose the following method to standardize the data processing:

$$p_{ij} = \frac{y_{ij}}{\sqrt{\sum_{i=1}^{n} y_{ij}^2}} \tag{6}$$

p_{ij} is the standardized data.

(4) Calculation and weight of the coefficient of variation:

First, we calculated the mean value of each metric:

$$A_j = \frac{1}{n}\sum_{i=1}^{n} p_{ij} \tag{7}$$

A_j is the mean of the j th.

Secondly, the standard deviation of each index is obtained as follows:

$$\sigma_j = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(p_{ij} - A_j)^2} \tag{8}$$

σ_j is the standard deviation.

Then, we calculated the coefficient of variation as:

$$v_j = \frac{\sigma_j}{A_j} \tag{9}$$

v_j is the coefficient of variation.

After calculation, we finally get the weight:

$$t_j = \frac{v_j}{\sum_{j=1}^{n} v_j} \tag{10}$$

t_j is the weight.

2.1.3 Comprehensive weight method

In order to reduce the actual error caused by the subjective and objective evaluation as far as possible, we combined the subjective and objective weights through the combination weight method to form the comprehensive weight for follow-up calculation. The specific steps include: the weight linear combination, the establishment of the objective function, the objective function solving the best value and the weight combination.

(1) A linear combination of the weights

We define K_j as a linear combination of the two weights, namely:

$$\mathrm{K}_j = \alpha m_j + \beta w_j \tag{11}$$

And, we define that:

$$\alpha + \beta = 1 \tag{12}$$

m_j is the subjective weight of the j th index obtained by the G1 empowerment method and w_j is the objective weight of the j th index obtained by the coefficient of variation.

(2) Establish the objective function

We construct the deviation between the combined and subjective weights and the deviation between the combined and the objective weights, and establish the objective function by establishing the sum of squares of the two:

$$d = \sqrt{\sum_{j=1}^{m}\left[\left(K_j - m_j\right)^2 + \left(K_j - w_j\right)^2\right]} \tag{13}$$

d is the objective function.

To facilitate the operation, we further processed it:

$$Q = d^2 = \sum_{j=1}^{m} \left[\left(K_j - m_j \right)^2 + (K_j - w_j)^2 \right] \tag{14}$$

Q is the processed objective function.

We substitute Equation (11) to Equation (14), and we obtain that:

$$Q = d^2 = \sum_{j=1}^{m} \left[\left(\alpha m_j + \beta w_j - m_j \right)^2 + (\alpha m_j + \beta w_j - w_j)^2 \right] \tag{15}$$

(3) The solution maximum value of the objective function

To obtain the minimum value, we derivative it and obtain the corresponding solution as follows:

$$\alpha = \beta = 0.5 \tag{16}$$

(4) Weight combination

We calculate it according to the corresponding value (11), and obtained the comprehensive weight:

$$K_j = 0.5 m_j + 0.5 w_j \tag{17}$$

Among them, K_j is the comprehensive weight.

After the calculation of equation (11) to equation (15), we can get that the influence of the subjective and objective weight on the comprehensive weight is 50%, that is, the two have the same influence as the comprehensive evaluation weight.

2.2. Score part

In order to avoid the problem that it is difficult to evaluate qualitative and quantitative indicators uniformly, we adopted the scoring method of trigonometric fuzzy number to unify qualitative and quantitative indicators to facilitate evaluation [11]。

We define the classification of the experts

$$G_{ij} = (a_{ij}, b_{ij}, c_{ij}) \tag{18}$$

G_{ij} is value from the experts.

a_{ij} b_{ij} c_{ij} represent the lowest value, the most likely value and the highest value, respectively, and their size increases successively.

After that, we averaged the scores of each expert for each indicator to obtain the comprehensive triangular blur number.

$$F_{ij} = \frac{1}{m} \left(\sum_{k=1}^{m} a_{ij}^k, \sum_{k=1}^{m} b_{ij}^k, \sum_{k=1}^{m} c_{ij}^k \right) \tag{19}$$

F_{ij} is the data in row i and column j.

Finally, we combined it linearly according to a certain weight ratio, and obtained the final score S of each comprehensive each expert.

2.3. Comprehensive evaluation

We linearly combined the resulting composite weights with the composite score to confirm that the final score was obtained [11]。

$$sum = K_1 S_1 + K_2 S_2 + \cdots + K_m S_m \tag{20}$$

sum is the final score and S_i is the comprehensive expert score of the i th index.

Finally, we compare the quality of each item by comprehensively scoring it to get the ranking of each item.

3. Example measurement

3.1. Determination of the index system

Through the investigation of mine restoration and a large number of literature query, we conclude that the state of land, vegetation restoration, water environment restoration, mine social benefit is the important index of mine repair good and bad, and then on this basis, we through comprehensive analysis, to this several important indicators established 14 secondary indicators, the relationship between indicators, as shown in figure 2, such as table 2:

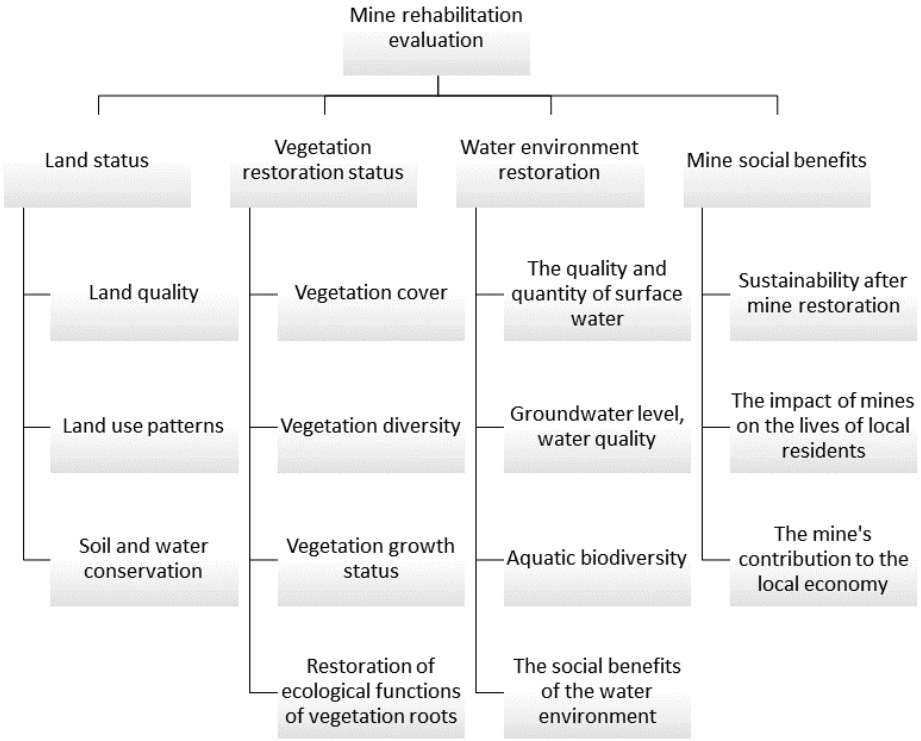


Figure 2. Evaluation index system diagram of mine restoration

Table. 2 Evaluation index system for mine restoration

Level 1 indicators	Secondary indicators	Index code	Index description	The calculation method of the indicators
Land status	land quality	X_1	Soil fertility, soil layer depth, moisture content, ph and other soil indicators	Through the field survey, soil sampling and analysis methods
	Land use patterns	X_2	The purpose, method and degree of land use include cultivated land, forest land, urban construction land, etc	Through remote sensing image recognition and analysis
	Soil and water conservation	X_3	Soil erosion and soil fertility	Field investigation and evidence collection
Vegetation restoration status	Vegetation cover	X_4	Proportion of regional vegetation cover	Using remote sensing images for image analysis
	Vegetation diversity	X_5	Species diversity and ecosystem diversity in regional vegetation	By monitoring the biodiversity of the area
	Vegetation growth status	X_6	Growth status and health level of the vegetation	Using remote sensing analysis
	Restoration of ecological functions of vegetation roots	X_7	The restoration of ecological functions such as soil conservation and water regulation by vegetation roots	Through the root system investigation, the field investigation is obtained
Water environment restoration	The quality and quantity of surface water	X_8	Quality and water quantity status of surface water	Through the water environment monitoring, hydrological measurement methods
	Groundwater level,water quality	X_9	Water level and water quality status of the groundwater	Through groundwater monitoring
	Aquatic biodiversity	X_{10}	Species diversity and ecosystem diversity of aquatic organisms	It is obtained by the aquatic life survey and biodiversity monitoring methods
	The social benefits of the water environment	X_{11}	The economic, ecological and cultural benefits brought to the society after the restoration of the water environment	Calculate out by questionnaire survey, expert evaluation method
Mine social benefits	Sustainability after mine restoration	X_{12}	The ability and guarantee of the sustainable development of economy,	Through the field investigation, economic analysis,

			environment and society after the mine restoration	social assessment methods
	The impact of the mines on the lives of local residents	X_{13}	The impact of mines on the living quality and living environment of local residents	Through the social survey, questionnaire survey method
	The mine's contribution to the local economy	X_{14}	The contribution and impact of the mines to the local economy	Through economic analysis, data and statistical methods

By establishing effective and proper indexes, the comprehensive evaluation of mine restoration is carried out.

3.2. Score and weight determination process

In the above evaluation index system, after referring to relevant literature, on the basis of continuous research by other scholars, through the thinking and scoring of two experts, we got the scores of each evaluation index in A, B and C. After calculation, the comprehensive evaluation of each index of the three mines, as shown in Table 3:

Table 3. Comprehensive evaluation table of the mines

metric	mine A	mine B	mine C
X_1	3.375	2.7500	3.3750
X_2	3.5625	3.125	3.0625
X_3	3.4375	2.9375	2.4375
X_4	3.0000	3.0000	2.6250
X_5	3.625	2.8125	2.3750
X_6	3.2500	2.875	2.5625
X_7	3.375	3.2500	2.6250
X_8	3.2500	3.1250	3.2500
X_9	3.5000	2.5625	2.9375
X_{10}	2.8125	2.5000	2.8750
X_{11}	2.6250	3.1875	3.0625
X_{12}	3.5000	2.3750	2.5000
X_{13}	3.9375	3.2500	2.1875
X_{14}	3.5000	3.2500	2.5000

We used the scoring method and combined with equations (18) ~ (19) to obtain the comprehensive evaluation values in Table 3. On the above results, we combined the weights obtained by the G1 subjective weight method and the weights obtained by the coefficient of variation method with the combined empowerment method. Finally, we get its comprehensive weight.

3.3. Analysis of the results

Finally, by combining the comprehensive weight and the comprehensive score, the final score is obtained after data processing, as shown in Table 4:

Table 4. Final score table of the mines

mine	mine A	mine B	mine C
The final score	3.4054	2.9028	2.7675

After comparison, we obtained the ranking of three kinds of mines in mine restoration: a> b> c. After the analysis, the land quality is the most important among all the indicators, and the land use mode, soil and water conservation situation and vegetation diversity are relatively high. For mine A, it performs well in the influence of the mine on the local residents and the mine on the local residents, but it needs to be improved in the social benefits of aquatic biodiversity and water environment. For mine B, it needs to improve aquatic biodiversity and sustainability after mine recovery. For mine C, the impact of the mine on the life of local residents needs to be further strengthened.

4. Conclusion, together with the discussion

(1) Through the method based on comprehensive evaluation, integrating the G1 method and the coefficient of variation method, and through the combination of subjective and objective methods, the final weight takes into account both the subjective and objective aspects.

(2) Through the method of triangular fuzzy number, and integrating qualitative and quantitative indicators, the two indicators are combined for evaluation, which can make the results more perfect.

(3) Through the mine restoration and evaluation of the three mines, some indicators can be provided for reference for the restoration of their respective mines, which is conducive to the improvement of each mine.

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